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THE INSTITUTE OF OPTICS

ROCHESTER, NEW YORK

INVESTIGATIONS OF THE OPTICAL
DETECTION OF HYPERFINE RESONANCES
IN ALKALI VAPORS

Principal Investigator: C. O. Alley

Report No. 5

Contract No. DA-36-039 SC-87273

DA Project No. 3A99-15-001

with

U.S. Army Signal Research and
Development Laboratory
Fort Monmouth, New Jersey

5th Quarterly Progress Report
(15 May 1962 to 15 August 1962)

INVESTIGATIONS OF THE OPTICAL DETECTION OF HYPERFINE RESONANCES IN ALKALI ~~HALIDES~~ VAPORS

Object of Research:

New Techniques for Atomic Frequency Standards

Report No. 5

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U.S. Army Signal Research and Development Laboratory, Fort Monmouth, N. J.

under

Electronic Components Research Department Technical Guidelines, 28 September 1960
PR & C No. 61 - ELP/R - 4306

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Prepared by C. O. Alley, Principal Investigator

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I. PURPOSE

The purpose of this investigation is to conduct experimental and theoretical research on optical pumping techniques for obtaining non-equilibrium population distributions among atomic states, and on optical detection of Zeeman and hyperfine resonances in alkali vapors with particular reference to rubidium gas cell frequency standards. The investigation is a continuation and extension of research performed at Princeton University under Signal Corps contract DA-36-039 SC 70147. Some of the particular areas to be investigated further are the use of coherent pulse techniques for the reduction of line widths and the use of wall coatings for the inhibition of spin relaxation.

II. ABSTRACT

Experimental investigations using a vacuum ultraviolet monochromator have shown that a substantial degree of linear polarization of Lyman- α radiation (1216Å) can be produced by successive reflections at the Brewster angle ($\sim 60^{\circ}$) from cleaved surfaces of lithium fluoride. Two successive reflections gave a ratio of intensities in the plane of incidence and perpendicular to the plane on the order of 1:10, as determined by a third LiF surface as analyzer, with a transmission on the order of 10% for two reflections.

III. PUBLICATIONS, LECTURES, REPORTS, AND CONFERENCES

A discussion was had in Rochester with Dr. Robert Vessot of the Varian Associates, Bomac Division, on some of the problems of attaining 21 cm maser action in atomic hydrogen using optical

pumping for obtaining population inversions.

IV. FACTUAL DATA

A. Optical Pumping in Atomic Hydrogen

The interference terms were calculated for the cases of π and σ^+ optical pumping in hydrogen. These will be presented in a future report.

Some experimental work on polarizing Lyman-α radiation (1216Å) has been carried out using an ultraviolet monochromator designed by Professor K. Teegarden and Dr. A. Smith of the Institute of Optics. The polarizer consisted of two thin rectangular pieces of lithium fluoride cleaved from a larger crystal. Data supplied by the Harshaw Chemical Company, supplier of the crystals, permitted calculation of the Brewster angle for 1216Å as approximately 60°, which was verified by experiment. The pieces were mounted with the reflecting surfaces facing and parallel to one another such that light reflected from the first piece falls on the second at the same angle and is reflected out of the instrument. The useful range of angles of incidence was from 50° to 70°, being bounded above by a limit on the instrument's overall size and below by the onset of multiple reflection between the reflectors.

Mounted at the exit slit of the vacuum monochromator, the polarizer prepared the exit beam for analysis by a reflectometer containing a third piece of LiF which could be oriented with its plane of incidence either parallel or perpendicular to that of the polarizer. The reflection from this piece was $3 \pm 1\%$ in the perpendicular orientation and $45 \pm 15\%$ in the parallel

orientation indicating that polarization was achieved. Better estimates of the degree of polarization will be available after the solution of some alignment problems associated with the monochromator. The overall transmission through the polarizer was probably on the order of 10 per cent.

B. Optical Pumping in Rubidium

A solenoid to use with the concentric mu-metal shields was designed and partially wound. However, the successful use of center correction coils on a solenoid within concentric shields by Pipkins and co-workers at Harvard following calculations by W. Franzen of Boston University suggests that the solenoid be built in this way to achieve a more uniform field.

Rubidium lamps containing different buffer gases (neon, helium, and argon) were obtained from the Optios Company.

The matrix elements for rubidium 85 have been computed and tabulated in preparation for a calculation of the stochastic pumping and relaxation matrices.

V. CONCLUSIONS

Production of linear polarization of Lyman- α radiation (1216Å) by successive reflections from cleaved LiF surfaces at the Brewster angle ($\sim 60^{\circ}$) is experimentally feasible without excessive loss of intensity.

VI. PLANS FOR NEXT QUARTER

Little activity is anticipated since no graduate assistants in research will be available and the principal investigator's time will be largely occupied by research on optical masers by

preparation of a graduate course on Atomic Structure and Quantum Optics, and by activities as a government consultant on optical masers.

Further planning for experiments on optical pumping in atomic hydrogen will be carried out in collaboration with Dr. Robert Vessot of the Bomac Laboratories.

VII. IDENTIFICATION OF TECHNICAL PERSONNEL

		Number of Hours Charged to Contract
C. O. Alley	Principal Investigator Assistant Professor of Optics	240
M. Blair	Graduate Assistant in Research	400
L. Emmons	Graduate Assistant in Research	400

Mr. Larrimore B. Emmons received the B.S. degree from Lehigh University in 1957. He is engaged in research on the optical constants of surfaces in the vacuum ultraviolet as a candidate for the Ph.D. degree.

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